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Supplement 109

Proceedings of the Root-knot Nematode Conference

December 15, 1938.

BUREAU OF PLANT INDUSTRY

UNITED STATES DEPARTMENT OF AGRICULTURE

PROCEEDINGS OF THE ROOT-KNOT-NEMATODE CONFERENCE

Held at Atlanta, Georgia, February 4, 1938

Edited by
Jocelyn Tyler, U. S. Department of Agriculture

Plant Disease Reporter
Supplement 109 December 15, 1938

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LIST OF THOSE PRESENT:

G. M. Armstrong	South Carolina Experiment Station
K. C. Barrons	Alabama Experiment Station
H. P. Barss	U.S.D.A., Washington, D. C.
A. N. Brooks	Florida Experiment Station (Lakeland)
Edna M. Buhrer	U.S.D.A., Washington, D. C.
E. E. Clayton	U.S.D.A., Washington, D. C.
H. A. Edson	U.S.D.A., Washington, D. C.
S. B. Fenne	Extension Division, Tifton, Georgia.
S. R. Gibbons	U.S.D.A., Birmingham, Alabama
R. J. Haskell	U.S.D.A., Washington, D. C.
H. H. Hume	Florida Experiment Station
C. C. Johnson	Innis, Speiden and Co., New York
D. G. A. Kelbert	Florida Experiment Station (Bradenton)
S. G. Lehman	North Carolina Experiment Station
M. B. Linford	Pineapple Experiment Station, Honolulu, Hawaii
A. Meyer	Tennessee Experiment Station
E. G. Moss	Tobacco Station, Oxford, North Carolina
W. C. Nettles	South Carolina Experiment Station
C. F. Poole	U.S.D.A., Charleston, South Carolina
R. F. Poole	North Carolina Experiment Station
E. S. Prevost	South Carolina Experiment Station
N. A. Schappelle	South Carolina Experiment Station
C. D. Sherbakoff	Tennessee Experiment Station
F. L. Stark	Rhode Island Experiment Station
G. Steiner	U.S.D.A., Washington, D. C.
H. P. Stuckey	Georgia Experiment Station
A. L. Taylor	U.S.D.A., Tifton, Georgia
Jocelyn Tyler	U.S.D.A., Washington, D. C.
G. B. Vandenberg	Rohm and Haas Co., Philadelphia, Pennsylvania
B. L. Wade	U.S.D.A., Charleston, South Carolina
L. M. Ware	Alabama Experiment Station
G. F. Weber	Florida Experiment Station
R. Weindling	Clemson, South Carolina
C. B. Williams	North Carolina Experiment Station
S. A. Wingard	Virginia Experiment Station
V. H. Young	Arkansas Experiment Station

INTRODUCTION

The conference was called to order by Chairman H. Harold Hume with the following introductory remarks:

Those interested in nematode investigations can render a service by awakening other agricultural research workers to the gravity of the problems

in this field. On many occasions the results of research work affecting horticulture - such as fertilizer and variety trials - are confused by the entrance of the root-knot problem into the experiments. Root-knot is one of the most insidious and unsuspected drawbacks in the entire research field, because the effects of the underground organism are often attributed to other factors.

A word to the crop breeder: Any program that does not take nematode resistance into consideration is started off on a false basis. Tobacco varieties have been bred for resistance to black shank, and watermelon for resistance to wilt, but nematode resistance must still be developed in these plants. If a broader view of the needs had been taken in the beginning, the work would now be farther ahead, and on a sounder basis. As soon as nematode resistance is found in any variety, this factor must be brought at once into the breeding program.

Perhaps the question of eliminating nematodes from the soil has received too much emphasis. Our chairman is not interested in the complete elimination of nematodes from any piece of soil in the southern area, since they inevitably appear even in virgin soil after it has been worked for 2 or 3 years. Sanitation is important, if the measures are practical. The problem is to obtain sufficient freedom to grow a crop, and to learn how to get along with the remaining population.

The work of the U. S. Department of Agriculture, though excellent, is but a gimlet hole in a mountain. The larger phases of the problem affect the entire group of agricultural research men, - horticulturists, agronomists, plant pathologists, entomologists, soil scientists. Those who don't recognize this fact must be educated to it.

If there were no nematodes in the South and they should suddenly appear in their present numbers, they would be seen as the pestilence they are. Funds for their control would be supplied quickly and in large amount. Such was the situation which allowed complete eradication of the Mediterranean fruit fly. But the nematode problem rouses no particular interest. Nematodes are always working havoc, taking their toll of crops, sometimes causing complete destruction. We blind ourselves by accepting them as a matter of course. The problem is here; we live with it; but that is no solution. There must be a general awakening all along the line to the magnitude of this situation.

CHEMICAL AND HEAT TREATMENTS

Mr. A. L. Taylor reported on chemical treatments of field plots at Tifton, Georgia. Chlorpicrin fumigation was much more successful in 1936, in warm, dry soil covered with mulch paper, than in 1937 in damp soil,

with a soil temperature of only 19° C and no cover. In the most heavily treated of the 1937 plots, at 150 and 200 pounds per acre, 2 plantings of indicator crops totaling 110 days showed that the infestation was much reduced.

The 1937 tests of carbon disulfide confirmed the previous conclusion that the most efficient amount to use is 500 pounds per acre. To accomplish the same degree of control with carbon disulfide emulsion required 2,720 pounds of carbon disulfide per acre.

The following gave no nematode control: formalin, up to 1,088 gallons per acre, applied in furrows; cyanamid at 4,000 pounds per acre, carefully distributed through the soil; and a commercial preparation of the Cold Smoke Company called Root-Knot Control, up to 12,000 pounds per acre, which acted only as a fertilizer.

Dr. E. E. Clayton reported for Mr. J. G. Gaines, of the U. S. Department of Agriculture at Tifton, Georgia. Of the chemical treatments tested over several years in tobacco seed beds, chlorpicrin gave the best nematode control, and mercurials also appeared effective except that their toxic action persisted for a long time. Though too expensive for the average grower, a permanent buried-tile system at Tifton has proved a very effective way to sterilize the soil in plant beds. Mr. K. J. Shaw, working at Oxford, North Carolina, has combined various chemicals with the fertilizer for their temporary effect in giving the plants a good start. Red mercuric oxide at 50 pounds per acre reduced nematodes but was toxic to plants. Ferric oxide helped plant growth without killing nematodes. Various amounts of cyanogas, napthalene, and other materials had little effect on the amount of root-knot.

Mr. H. P. Barss presented for discussion a schedule of treatments proposed by Dr. G. H. Godfrey, of the Texas Experiment Station at Weslaco, to prepare 300 acres in East Texas for peaches. Areas shown by an indicator crop to be infested will be treated with 48 cc of chlorpicrin in each tree site. Trees are expected to become well established by the growth stimulation of the fumigant in addition to the relative freedom from root-knot, and thereby capable of withstanding later infestation. Dr. Godfrey's directions for the use of chlorpicrin included a warning that poisonous effects on the worker may be cumulative and have even been known to be fatal following exposures on successive days. Old plant remains in the soil should be disintegrated before treatment. The soil should be reasonably dry, should be loosened to the desired depth, and should be covered immediately with glue-coated paper - impervious, when unbroken, to chlorpicrin gas. A barrier of wet soil at the edge of the treated area is urged.

Mr. F. L. Stark, conducting tests of chlorpicrin at the Rhode Island Experiment Station for Innis, Speiden & Co., has found a gas mask unnecessary,

even in making greenhouse applications. The effective dose was at least 2 cc per cubic foot of soil, at average greenhouse soil temperatures and with roughly 20 percent soil moisture. A cover is important for nematode control, less so for fungi. The most serious injury by nematodes is to the young plants. The "partial-sterilization effect" of the chlorpicrin treatment more than doubled the yield of tomatoes. Tomato plants in untreated, infested soil grew to only 12 inches in 2 months, while those in treated soil grew to 4 feet or higher.

Mr. C. C. Johnson, of Innis, Speiden & Co., presented the first quarterly issue of the Larvacide Log, a collection of reprints on the use of chlorpicrin in agriculture, which will be sent to all who request it. Mr. Johnson reported that the minimum lethal dose of chlorpicrin for dogs is 120 parts per million for 30 minutes. Test men were forced out in 2 minutes from a concentration of 22 p.p.m. The presence of the gas is noticeable well below 1 p.p.m. The experience of the company's demonstrators indicate no injury in more than 10 years. Warning is, however, given against the use of chlorpicrin by persons subject to chronic pulmonary troubles.

A Vermorel injector for applying chlorpicrin costs about $35. Innis, Speiden & Co. has a new valveless type of applicator ready for testing.

Dr. G. Steiner remarked that stimulation to plant growth is not always an advantage. A field treatment on Long Island, for control of the bulb-and-stem nematode, increased available nitrogen in the soil, which in turn increased injury by basal rot which was brought in with the plants. Dr. M. B. Linford questioned whether the stimulating effect would carry over to a second year. No information was available on this point.

In relation to the treatment of individual tree sites, Mr. K. C. Barrons inquired how rapidly root-knot larvae can travel. Mr. Taylor reported his last summer's preliminary experiment on this subject. Nematodes from an inoculum of infested roots failed to reach the nearest plants, less than 18 inches away, in 4 months. Dr. Clayton stated that when tobacco beds are pan-steamed 8 to 10 inches deep, nematodes come up from below unless the seedlings are gotten off quickly.

Dr. Linford reported that the indicator plants in soil that had been treated, some time previously to planting, with a light application of tetrachlorethane, not sufficient to kill the nematodes, showed actually more galls of 1 nematode generation than did the plants in the control, untreated soil, which had stood fallow during the same period. Miss Jocelyn Tyler reported similar observations following soil treatment with light dosages of certain organic mercury compounds.

BIOLOGICAL CONTROL OF ROOT-KNOT

Dr. Linford presented his paper on natural enemies of the root-knot nematode, with lantern illustrations. A complex soil population has been found in Hawaii, composed of 12 species of nematode-trapping fungi - apparently the most important and the most widespread group of enemies; also 6 non-trapping parasitic fungi; a Penicillium which parasitizes almost every exposed egg mass to some extent; 24 predacious nematodes of the genera Mononchus, Aphelenchoides, Diplogaster, and Dorylaimus with its related genera; 6 predacious mites; 3 predacious tardigrades; and a possibly harmless ectoparasitic protozoan. The abundance and distribution of nematode enemies in agricultural soils in the continental United States should be studied. The wheat nematode, because available in large numbers, was suggested for use as a food supply in such a study. These enemies may be introduced into water-agar cultures with nematode-infested roots, with soil, or with a concentrated suspension of nematodes from soil. After incubation for a week or two, the enemies predominate in those plates in which the major available food supply consists of nematodes.

The decomposition of organic matter in the soil by bacteria and fungi furnishes food for the increase of free-living nematodes, which in turn feed whatever nematode parasites or predators are present so that the latter increase. In one experiment an enormous population of predacious mites was built up in this way. Nematodes washed from these soils frequently carry fungous parasites. As the enemies increase in numbers and in activity, they attack root-knot larvae as well as free-living nematodes. Experiments on the addition of organic matter to infested soils, showing the increase of saprophytic and predacious nematodes and the ultimate decrease of root-knot, are reported in Soil Science for February, 1938. Desirable trapping fungi can be added to root-knot infested soils - one of the practical applications that will repay further study along the many lines suggested in this important work.

CULTURAL AND SANITATION PRACTICES

Dr. Clayton presented another report from Mr. Gaines. Removal of old roots and drying of soil with frequent stirring in hot weather have given a slight reduction of root-knot but no indication of practical control. A winter cover of rye has increased the value of the tobacco crop by adding organic matter, without any indication of nematode control. In infested soil, early planting gives the best chance of a good crop. Probably the time of nematode penetration in relation to the growth of the plants is important. Mr. W. M. Lunn at Florence, South Carolina, has observed that a high potash fertilization gives a better tobacco crop because it prevents some of the destructive decay of galls.

Dr. Steiner remarked that heavy potash fertilization is reported to decrease the damage to sugar beets by the nematode Heterodera schachtii. The mechanism is not fully understood. Potash increases the oxygen consumption of the roots by increasing the iron metabolism. In this way root formation and root growth are favored.

Dr. Clayton and Dr. R. F. Poole reported further experiments of Mr. Shaw. The tobacco yield was sometimes doubled by applying fertilizer under the plants rather than in bands at the side, and by application just before planting rather than 10 days earlier. Ridge cultivation reduced damage to tobacco by stimulating root growth.

Mr. Taylor observed, on the other hand, that in ridging lima beans no secondary roots were produced, and that stems as well as roots became filled with nematodes.

Dr. Steiner discussed the problems of forest nurseries in the shelberbelt area established without considering the presence of root-knot in the sites. Evergreen stock formerly grown for soil conservation presented no nematode problem. Pine has only once been reported as a host of the root-knot nematode. (If it is again found infested, the information and specimens should be sent to Dr. Steiner's office). Mulberry seedlings are tolerant of root-knot, and appeared to grow normally in these nurseries although their roots were beaded with galls. Black-locust seedlings, on the other hand, suffered from the infestation by blinding of root tips and cracking of the root cortex. The main problem here involved is not that of the amount of damage caused by root-knot on these mulberry, catalpa, or black-locust seedlings. It is a problem of sanitation and prevention. Even if the infestation is slight when these seedlings are distributed, by persisting at the new planting site it becomes a permanent source of contamination, particularly if the trees are planted in erosion gulleys from where runoff water may further distribute the infestation. Black-locust seedlings appear to tolerate the standard hotwater treatment for the control of root-knot (118° F. for 1/2 hour). Small-scale experiments gave 100 percent control, but under commercial conditions the results may be less satisfactory and further increase the production costs to an unprofitable level. The importance of selecting clean nursery sites and of enforcing strict sanitation is therefore emphasized. Certain nurseries in root-knot-free regions have benefited enormously by marketing clean stocks of ornamentals.

Professor Hume reported that virgin "flatwoods soils" in Florida are free from root-knot until contaminated. Clean peach seed in such soil will give one crop of clean seedlings without particular sanitary precautions. The second crop is doubtful. Thereafter the land is unfit for nurseries.

Dr. B. L. Wade mentioned that certain California quarantine inspectors certify shipments as "relatively" rather than "absolutely" free from root-knot. Dr. Steiner mentioned the tuberose industry of North Carolina, where virgin lands have been used so far. The seed tubers have, however, become infested, and the usual hot-water treatment at 118° F. appears inadequate. Nematode egg masses are protected inside the woody tissues, especially after the tubers have been dried all winter. However, growth and blooming are actually improved by a treatment of 30 minutes at 126° F. which also controls satisfactorily the root-knot infestation.

DISEASE RESISTANCE

Miss Edna M. Buhrer reported 133 additions to the host list since the Nashville meeting last year, including plants of 5 families not previously reported, bringing the total to 1288 hosts. A supplement to the list published in 1933 has been issued in the Plant Disease Reporter for July 1, 1938 (vol. 22, no. 12).

Professor Hume stressed the importance of information on resistant species and varieties in susceptible genera and species. Dr. Clayton reported progress in the broad-scale tobacco-breeding program. Several types of Nicotiana tabacum show little evidence of nematode infestation. Other types show abundant galls which seem not to injure the plant because they are small and do not decay. The root-knot-resistant varieties come from Central America.

Miss Tyler made a progress report on experiments with resistant ornamentals. None of the 29 marigold varieties tested remained free from infestation though in many cases the few galls were so small that it required the most minute search to find them. The conclusion from one summer's observations is that African varieties (Tagetes erecta), including all odorless marigolds, seem relatively resistant, while more infestation was found in the French varieties (T. patula), all odorous. After a long season under greenhouse conditions, some plants became heavily infested with normal gall formation and the production of viable eggs. The 37 varieties of zinnias tested were all heavily infested except possibly the Mexican varieties. Tolerance of a heavy infestation is still to be determined.

Mr. Barrons told of his discovery that very young seedlings of so-called resistant plants, such as Crotalaria, Alabama No. 1 bean, cowpea varieties Conch, Victor, and Iron, rye, wheat, oats, and other grasses, were entered by larvae equally with seedlings of okra, tomatoes, Kentucky Wonder bean, and other susceptible plants, when seeds were planted in heavily inoculated soil in the greenhouse. Not all the seedlings of any plant were attacked, but there was no significant statistical difference between the different kinds of plants tested in numbers of larvae found in the roots. Further development of the nematodes in these young plants was not tested.

Mr. Barrons quoted Dr. Linford's suggestion made in this connection at the meeting of the Horticulture Section, that if larvae should enter a resistant plant and fail to develop, our conception of the trap crop might be so changed as to combine the functions of trap crop and green manure in one resistant species.

Mr. Barss expressed the opinion that freedom from infestation is less significant from a practical standpoint than is the satisfactory growth of plants which are necessarily infested. He considers the search for tolerant plant varieties 100 percent worth while.

Dr. Wade told of the Vegetable Breeding Laboratory established 2 years ago at Charleston, South Carolina. The probable value of nematode-resistance studies in connection with the program as a whole was discussed at that time. Reports on resistant plants and on biological control of nematodes now give encouragement that much should come from strictly scientific work on varietal resistance. Within our large host list there is needed an exhaustive study of the reactions of species, varieties, and horticultural types. The experimental inoculation of these plants of course presents difficulties, in view of our present lack of information on nematode strains and populations. The Charleston laboratory has collected hardy plant materials from a number of sources, for testing by 13 collaborating stations. Interest in nematode resistance in combination with other breeding programs has recently trebled, since root-knot has vitiated some of the studies on resistance to other diseases. There seems to be no nematode problem in the commercial trucking areas around Charleston, where potash fertilizers have been used too heavily for the best production of beans, cabbage, and other crops. The relation of nematodes to soil types should be analyzed.

Dr. H. A. Edson offered, in view of the dearth of information on varietal resistance within plant species, to open the Plant Disease Reporter to lists of more or less resistant varieties. Observations need not be checked, but should be accompanied by a brief, informative statement of the growing conditions. Dr. Steiner suggested, with Dr. Edson's approval, that the Plant Disease Reporter also invite exact calculations of the damage done by root-knot to specific crops. Data are not now available for answering frequent inquiries, such as how root-knot might affect the yields of tung-oil trees in a 30,000-acre planting in Mississippi.

Mr. Barss suggested that the stations which are breeding vegetables for southern conditions should work individually and together to institute uniform and dependable tests on nematode resistance, searching endless progeny lines to find possible resistance, as was done, for example in the case of barley scab. He also suggested that Mr. Barrons' summary of crops already bred for nematode resistance be published with the proceedings of this meeting. Mr. Barrons mentioned the pertinent fact that the occurrence of

soil infestations is often spotty and leads the unwary to erroneous conclusions. Dr. Linford's findings on nematode enemies may be of significance in this connection. Dr. Clayton supported the recommendation that spottily infested soils should be avoided in experiments on resistance or on the effects of soil treatments. There are areas where nematode populations can not be built up. In a plot near Raleigh, North Carolina, where the surface soil was of a uniform type, tobacco roots developed a uniformly heavy infestation over the friable Norfolk-loam subsoil, but only a spotty infestation over the adjacent Marlboro-clay subsoil. Where the indicator crop showed spotting, Mr. Barrons solved the problem for his purposes by mixing large amounts of inoculum (chopped galls) in the row at planting time, equal amounts over equal areas. Professor Hume suggested that we may in the end be forced to pot experiments, where soils can be mixed uniformly.

Professor Hume warned against condemning certain plants because of occasional reports of nematodes found in them. There are undoubtedly groups of plants in which resistance is the rule, infestation the exception. For example, in handling many hundreds of Hemerocallis plants, of many varieties, Professor Hume has found only 1 sample infested. In this case, resistance is the positive situation, and it is misleading to list such a plant as a host.

ORGANIZATION

Chairman Hume announced the organizing committee for the coming year: Doctors Clayton, R. F. Poole, Sherbakoff, Steiner, Stuckey, Wingard, and Mr. Barrons. Professor Hume was again drafted as chairman. One-year leaders were appointed for special subjects, to correlate the projects of scattered workers and to arrange for reports at the next meeting:

Breeding for resistance - Mr. Barrons.

Host plants - Miss Buhrer.

Chemical and heat treatments - Mr. Taylor.

Rotations - Mr. Gaines.

Cultural practices - Mr. K. J. Shaw.

Biological control - Dr. J. N. Couch.

--And may Dr. Linford and Dr. Wade not forget us!

VARIETAL DIFFERENCES IN RESISTANCE TO ROOT-KNOT IN ECONOMIC PLANTS

Keith C. Barrons
Alabama Agricultural Experiment Station
Auburn, Alabama

INTRODUCTORY REMARKS

Observations on varietal differences in resistance to root-knot in economic plants are here compiled from the viewpoint of the plant breeder. This list of more or less resistant plants includes certain species of little immediate economic value because they might be of use in breeding work or as understocks for clonal propagation. For the purposes of this review the term "resistant" is intended to indicate some ability to resist the root-knot disease or injury caused by the nematode, Heterodera marioni. Recent experiments by the writer (3) indicate that root-knot-nematode larvae enter the roots of certain resistant plants at as great a rate as they enter susceptible plants. Resistance to root-knot therefore appears to be due to something within the plant that either kills the larvae or counteracts their gall-inducing effect. It is, therefore, suggested that the term "root-knot-resistant" is more specific than "nematode-resistant".

Steiner (26) has pointed out cases of host specialization and host preference among different populations of H. marioni. Cases have been known where certain plants appeared resistant to one nematode population and susceptible to another. Assuming that this host specialization may be extended to varieties within a plant species, it is possible that certain ones of the varieties mentioned in the literature as resistant may prove susceptible when tested under other circumstances. Hereditary variations or strain differences within a plant variety may also account for discrepancies between reports in literature and observations subsequently made by other experimenters. Iron and Brabham cowpeas (q.v.) are an example.

LIST OF PLANTS REPORTED AS EXHIBITING RESISTANCE TO ROOT-KNOT

Amygdalus communis L. (Almond)

Tufts and Day (28) in California tested 15 commercial varieties, seedlings of several crosses of known parentage, and two "bitter" almond seedlings. No lot proved uniformly resistant; however, certain individual seedling plants did not develop root-knot. According to Currie (9) the above workers are attempting to breed a resistant strain from these seedlings.

Amygdalus persica L. (Peach and Nectarine)

McClintock (20, 21) reported that the seedlings of a certain old seedling peach tree growing in Florida were highly resistant to root-knot.

Tufts and Day (27, 28) in California reported that seedlings of the Shalil and Bokhara peaches were practically immune from root-knot, while the Honey and the Saucer types were somewhat less susceptible than the average peach. Later tests indicated that the Bokhara seedlings were not so resistant as previously supposed (9), which, together with the fact that they are relatively shy bearers, has led this variety to be discarded as a possible rootstock for general use. As peach seedlings make good rootstocks for most of the stone fruits, trees of the Shalil variety are being planted rather extensively for seed propagation. Seedlings of certain introductions from Yunnan Province, China, also appeared resistant.

Among the 44 nectarines tested by Tufts and Day (28), seedlings of the Quetta variety were tentatively classed as resistant.

Hutchins (14) at Fort Valley, Georgia reported seedling rootstocks of Shalil highly resistant to root-knot and very satisfactory in other respects. Both seedling understocks and clonally propagated rootstocks of F.P.I. 61302 (a cross between Bolivian Cling and Quetta nectarine) have proved resistant and have produced trees of a vigorous growth.

Ananas sativus Schult. f. (Pineapple)

Collins and Hagan (7, 12) made statistical analyses of the growth of different parts of diseased and non-diseased plants. Considering the development of the entire plant and the extent of root injury, Wild Brazil and Lot 520 - a vegetatively reproduced hybrid of Cayenne x Wild Brazil - were the most tolerant to nematode attack. The other varieties tested, in order of decreasing tolerance, were Wild Kailua, Natal, Pernambuco, Hilo, Cayenne, Ruby, and Taboga. Of the two varieties grown commercially in Hawaii, Hilo consistently appeared slightly superior to Cayenne although both are quite susceptible.

Avena sativa L. (Oats)

Bessey (5) stated that some oat varieties (names not mentioned) were resistant but others susceptible.

Citrus spp.

Neal (22) recommended the so-called sour orange as nearly "disease-proof" with respect to root-knot. He also reported Citrus trifoliata and Satsuma orange to be resistant on the basis of brief trials.

Webber and Orton (29) stated that one of the writers dug oranges in all parts of Florida without finding evidences of root-knot. Citrus species are generally considered resistant at the present time.

Cydonia spp. (Quince).

Tufts and Day (28) reported that cuttings of the following varieties stood in the nursery two years without developing a single root knot: Rea, Orange, Burbank, Angers (= Gregory), S.P.I. 33214, and the East Malling stocks A, C, and D.

Dahlia spp. (Dahlia)

Schmidt (24) reported 13 varieties of dahlias as severely, 9 as moderately, and the following 19 as lightly infested: Jane Cowl, Fort Monmouth, Jean Trimbee, City of Trenton, White Wonder, Alice Whittier, Lady Moyra Ponsonby, Mrs. Bruce Collins, Robert Emmett, Ida Perkins, Long Hill, Dancing Sultana, Monmouth Radiance, Satan, Fordhook Marvel, Little Edith (Pompon), Gertrude (Pompon), Atom (Pompon), Yankee King.

Dianthus spp. (Pink, carnation, etc.)

Goff (11) noted considerable variation, possibly due to hereditary differences in susceptibility, between different types of Dianthus and within certain types (variety names not mentioned), and suggested developing highly resistant strains by selection.

Diospyros spp. (Persimmon)

According to Hume (4), native persimmons are quite free from root-knot damage and make good rootstocks for the Oriental varieties, some of which may also prove resistant.

Ficus spp. (Fig)

Bessey and Byars (6) mentioned that the figs Celeste and Poulette were claimed to be less susceptible than other varieties.

Gossypium spp. (Cotton)

King (4) reported that Acala has replaced Egyptian varieties in Arizona owing in part, at least, to its resistance to root-knot. Certain first-generation hybrids have also been found resistant, but segregation occurred in succeeding generations.

Ipomoea batatas Poir. (Sweetpotato)

Weimer and Harter (30) in California found the varieties Red Jersey, Yellow Belmont, and Southern Queen to be resistant. Only a few galls were found on Little Stem Jersey, Big Stem Jersey, and Porto Rico. In Nancy Hall and Red Brazil there was a considerable decrease in yield.

Poole and Schmidt (23) in North Carolina found the Jersey and Porto Rico varieties to be highly resistant, while Norton Yam, Yellow Yam, Southern Queen, Red Bermuda, Nancy Hall and other varieties were susceptible.

Ligustrum spp. (Privet)

Hume (4) stated that L. quihoui has been found free from root-knot and is useful as an understock for other species of this genus.

Lycopersicum esculentum Mill. (Tomato)

Malloch (19) found 98 tomato varieties and 8 hybrids to be susceptible, but made no attempt to distinguish degrees of susceptibility.

The writer has observed in four separate plantings in naturally infested soil during two successive years that the varieties Stone and Red Rock produced healthier plants than other common varieties. Galls on these roots averaged smaller, terminal galls were fewer, and the root system as a whole was better developed. These observations could not be confirmed in tests subsequently conducted in artificially inoculated soil where a heavy primary infestation took place. Apparently these two varieties are tolerant to a moderate root-knot infestation, owing to their general vigor and extensive root systems. If a large number of larvae enter the roots when the plants are still young, then root growth is impeded and large galls are formed.

Magnolia spp.

Hume (4) suggested M. grandiflora as a resistant rootstock for the deciduous magnolias.

Malus spp. (Apple)

In one small test of apple trees made by Tufts and Day (28) seedlings of the variety Rainier (M. sylvestris) were not attacked.

Nicotiana spp. (Tobacco)

According to Garner, Allard, and Clayton (10) all domestic varieties are susceptible except a strain of Orinoco known as Faucette Special, which shows moderate resistance.

Bessey and Byars (6) reported "some strains" of tobacco developed by selection as not diseased. Such strains are not known at present.

Phaseolus lunatus L. (Lima bean)

Hopi 155, bred by W. W. Mackie of the California Experiment Station, is being used for the commercial production of baby limas in certain root-knot-infested areas in California and is available for seed purposes from a few growers. Among the limas recently sent out for trial by the California Station, Hopi 5987, 5988, and 5992 proved superior in root-knot resistance to Hopi 155 in a one-year test by the writer at Auburn. The Hopi limas possess resistance to a notable degree when compared with the common lima bean varieties, but less than Alabama No. 1 and Alabama No. 2 common beans (17). At the Alabama Station, Hopi limas are being used as breeding material in an attempt to develop lima-bean varieties especially adapted to southern conditions and highly resistant to root-knot.

King reported (4) having collected highly resistant but mottled lima-bean strains from the Hopi Indians.

Phaseolus vulgaris L. (Bean)

Two strains of beans - since named Alabama No. 1 and Alabama No. 2 - were reported by Isbell (15) to be highly resistant to root-knot. They have been carefully tested at the Alabama Experiment Station over a period of five years in naturally infested soil as well as under conditions of artificial inoculation. On only a few occasions have they been observed to develop root-knot galls. For the most part these have been found on old plants which had ceased production.

As reported by Isbell and Barrons (17) Alabama No. 1 is being introduced by the Alabama Experiment Station in 1938 and will be available through commercial sources in subsequent years. A number of new root-knot-resistant strains have been developed at the Alabama Station by utilizing Alabama No. 1 and Alabama No. 2 in hybridization and selection work. The best of these will be introduced after adequate tests. In resistance studies with more than 30 varieties of beans the writer (2) found Surecrop Stringless Wax also slightly resistant. These 3 were the only varieties exhibiting sufficient resistance to be of possible use in breeding work.

Prunus spp. (Apricot)

The apricot has long been known to be resistant to root-knot (28), and has been used with fair success as a rootstock for plum and peach. Tufts and Day (28) tested 48 varieties of P. armeniaca, P. mume, and P. dasycarpa for two to three years; no root-knot developed. Hutchins (14) found the common apricot and the Japanese apricot (P. mume) and also a plum (P. hortulana) resistant but unsatisfactory as peach understocks.

Prunus spp. (Cherry)

Tufts and Day (28) found no infestation on seedlings of Mazzard, English Morello, Stockton Morello, Montmorency Monarch, and P. demissa in tests extending over one or two seasons.

Prunus spp. (Plum)

The Marianna plum has been used with success as a rootstock for various cultivated plums and peaches in infested soil. Neal (22) reported this plum as free from root-knot during a three-year test. McClintock (20) also found its seedlings resistant. Tufts and Day (28) found rooted cuttings from 25 different Marianna seedlings to be free from galls. Rooted stem cuttings of Myrobalan from different sources showed considerable variation in degree of infestation. Three of these clones proved vigorous and offer possibilities as rootstocks. The wildgoose plum, P. munsoniana, was also free from root-knot in their nursery.

Pyrus spp. (Pear)

According to Tufts and Day (28) seedlings of the varieties P. Barry, Easter Beurre, and Hardy showed less root-knot than others in a two-year test of ten varieties. In a one-year test seedlings of Pyrus variolosa were free.

Rosa spp. (Rose)

According to Hume (4), much variation exists in root-knot injury to roses although none are immune. Mme. Plantier of the China rose group, often used as a rootstock in the South, was mentioned as "not badly affected".

Soja max (L.) Piper (Soybean)

McClintock (20) stated that the Biloxi, Laredo, and O-too-tan soybeans are resistant to root-knot, and they have been so described in numerous seed catalogs. The writer has observed that Biloxi is almost free from galls even in artificially inoculated soil.

Solanum tuberosum L. (Potato)

Cunningham (8) found that Green Mountain, Bliss Triumph, and Irish Cobbler were equally susceptible to root injury, but that the latter variety showed much less tuber injury.

Vigna sinensis (Torner) Savi (Cowpea)

Webber and Orton (29) demonstrated that the Iron variety was resistant to root-knot. It has now been in commerce for 35 years and has commonly been known as a resistant strain suitable for rotations. The writer tested samples from five different sources in uniformly inoculated soil. Two of the samples were uniformly resistant, two developed root-knot galls to a mild degree, and one appeared susceptible although the galls were not so large nor so numerous as on many other cowpea varieties. Variations were found also with respect to date of maturity and habit of growth, indicating that there are definite strains of the Iron cowpea now in commerce.

Brabham is another resistant variety which is reported to be the result of a cross between Iron and Whippoorwill. Taylor (4) has found infestation in both Iron and Brabham, and considers this due to impurity in commercial seeds. The resistant Victor cowpea is the result of a more recent cross, by the United States Department of Agriculture, between varieties Brabham and Groit (13).

Isbell (16) tested 21 varieties of cowpeas in soil badly infested with root-knot, comparing the important table varieties with a few field varieties. Conch was the most resistant variety tested; California Black Eye, Extra Early Black Eye, Purple Hull, and Six Weeks were all less susceptible than many other varieties; Victor was only slightly resistant.

Kendrick (18) reported the Calva Blackeye as resistant to wilt and to root-knot. Numbered strains have been distributed for testing.

The Kilgore Seed Company of Plant City, Florida, catalogs a variety called Suwannee, which "ranks with Iron and Brabham in resistance to root-knot".

Viola spp. (Violet)

Webber and Orton (29) quoted a Mr. P. H. Dorsett as observing great differences in susceptibility of greenhouse violet plants. No varieties were mentioned.

Vitis spp. (Grape)

Neal (22) stated that V. cordifolia and vulpina stocks proved superior for vinifera grapes owing to the high susceptibility of the latter roots. Bessey and Byars (6) reported American grapes to be more resistant than European varieties.

Snyder (25) reported some inherent resistance to root-knot in stocks of V. doaniana, V. champini, V. longi, V. cinerea. Those most promising as useful resistant rootstocks were the varieties Dog Ridge (V. champini), Salt Creek (V. doaniana), and hybrid 1613 from the cross Solonis (V. longi) x Othello (V. riparia x V. labrusca) x V. vinifera).

Warneria spp. (Gardenia)

According to a note in Florist's Review (1), J. E. Hendry of Fort Meyers, Florida, has found W. thunbergia to be resistant to root-knot. In subsequent correspondence Mr. Hendry has stated that this species is continuing to prove resistant after a number of years of testing, and is a suitable rootstock for W. augusta (G. florida) as well as for a number of varieties of W. veitchi.

LITERATURE CITED

1. Anonymous. Top-worked gardenia. Florists' Rev. 78(2006):13. 1936.
2. Barrons, K. C. A method of determining root-knot resistance in beans and cowpeas in the seedling stage. Jour. Agr. Research (U.S.) 57: 363-370. 1938.
3. _____ Studies on the nature of root-knot resistance. Jour. Agr. Research (U.S.) (in press).
4. Barss, H. P., and others (editors). Proceedings of the root-knot nematode conference. U.S.D.A. Plant Disease Rep. Sup. 102. 1937.
5. Bessey, E. A. Root-knot and its control. U.S.D.A. Bur. Plant Indus. Bull. 217. 1911.
6. _____ and L. P. Byars. The control of root-knot. U.S.D.A. Farmers' Bull. 648. 1915.
7. Collins, J. L., and H. R. Hagan. Nematode resistance of pineapples. Varietal resistance of pineapple roots to the nematode Heterodera radicicola (Greef) Müller. Jour. Heredity 23: 459-465; 503-511. 1932.
8. Cunningham, H. S. The root-knot nematode (Heterodera marioni) in relation to the potato industry on Long Island. N. Y. (Geneva) Agr. Expt. Sta. Bull. 667. 1936.
9. Currie, J. H. Looking over nematode resistant rootstocks. Pacific Rural Press 133: 628. 1937.
10. Garner, W. W., H. A. Allard, and E. E. Clayton. Superior germ plasm in tobacco. U.S.D.A. Yearbook 1936: 785-830. 1936.
11. Goff, C. C. Relative susceptibility of some annual ornamentals to root-knot. Florida Agr. Expt. Sta. Bull. 291. 1936.

12. Hagan, H. R., and J. L. Collins. Studies on varietal resistance of pineapple plants. Part II. Plant resistance to Heterodera marioni (Cornu) Goodey. Jour. Heredity 26: 35-46. 1935.
13. Hayes, H. K., and R. J. Garber. Breeding crop plants. (Ed. 2) 438 pp. McGraw-Hill Book Company, New York and London. 1927.
14. Hutchins, L. M. Nematode-resistant peach rootstocks of superior vigor. Amer. Soc. Hort. Sci. Proc. 34: 330-338. (1936). 1937.
15. Isbell, C. L. Nematode-resistance studies with pole snap beans. Jour. Heredity 22: 191-198. 1931.
16. _____ Nematode injury to the roots of table varieties of cowpeas. Ala. Agr. Expt. Sta. Ann. Rept. 45: 29-30. 1934.
17. _____, and K. C. Barrons. Breeding root-knot resistant beans for southern growers. Southern Seedsman 1: 7, 26-27. 1938.
18. Kendrick, J. B. A cowpea resistant to fusarium wilt and nematode root knot. (Abstract) Phytopath. 26: 98. 1936.
19. Malloch, W. S. The problem of breeding nematode-resistant plants. Phytopath. 13: 436-450. 1923.
20. McClintock, J. A. Report on resistant plants for root-knot nematode control. Georgia Agr. Expt. Sta. Circ. 77. 1922.
21. _____ The transmission of nematode resistance in the peach. Science (n.s.) 58: 466-467. 1923.
22. Neal, J. C. The root-knot disease of the peach, orange, and other plants in Florida. U.S.D.A. Div. of Ento. Bull 20 (old ser.) 1889.
23. Poole, R. F., and R. Schmidt. The nematode disease of sweet potatoes. Phytopath. 17: 549-554. 1927; North Carolina Agr. Expt. Sta. Bull. 265. 1929.
24. Schmidt, R. Relative susceptibility of certain varieties of dahlias to root-knot nematode. U.S.D.A. Plant Disease Reptr. 21: 32-33. 1937.
25. Snyder, E. Susceptibility of grape rootstocks to root knot nematode. U.S.D.A. Circ. 405. 1936.
26. Steiner, G. The problem of host selection and host specialization of certain plant-infesting nemas and its application in the study of nemic pests. Phytopath. 15: 499-534. 1925.
27. Tufts, W. P. Nematode resistance of certain peach seedlings. Amer. Soc. Hort. Sci. Proc. (1929) 26: 98-100. 1930.
28. _____, and L. H. Day. Nematode resistance of certain deciduous fruit tree seedlings. Amer. Soc. Hort. Sci. Proc. 31 (suppl.): 75-82. 1934.
29. Webber, H. J., and W. A. Orton. A cowpea resistant to root-knot (Heterodera radicicola). U.S.D.A. Bur. Plant Indus. Bull. 17, article 2. 1902.
30. Weimer, J. L., and L. L. Harter. Varietal resistance of sweet potatoes to nematodes, Heterodera radicicola (Greef.) Müller, in California. Phytopath. 15: 423-426. 1925.